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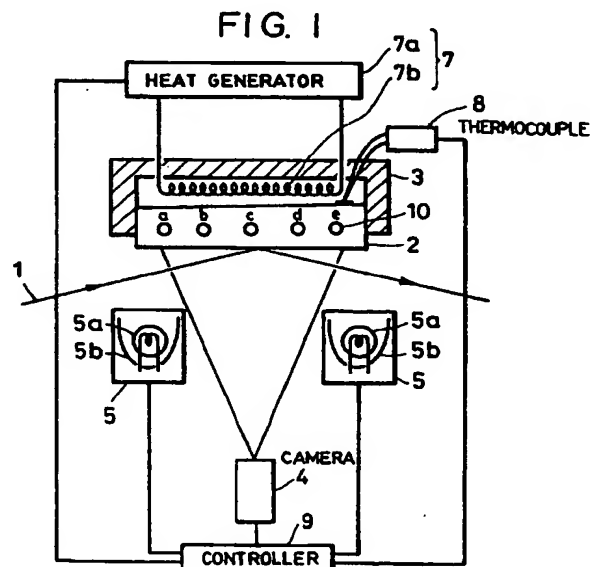
⑦① Applicant : **CANON KABUSHIKI KAISHA**  
**30-2, 3-chome, Shimomaruko, Ohta-ku**  
**Tokyo (JP)**

⑦② Inventor : **Niibe, Masahito, c/o Canon**  
**Kabushiki Kaisha**  
**3-30-2, Shimomaruko**  
**Ohta-ku, Tokyo (JP)**  
Inventor : **Fukuda, Yasuaki, c/o Canon**  
**Kabushiki Kaisha**  
**3-30-2, Shimomaruko**  
**Ohta-ku, Tokyo (JP)**  
Inventor : **Hayashida, Masami, c/o Canon**  
**Kabushiki Kaisha**  
**3-30-2, Shimomaruko**  
**Ohta-ku, Tokyo (JP)**

⑦④ Representative : **Beresford, Keith Denis Lewis**  
**et al**  
**BERESFORD & Co. 2-5 Warwick Court High**  
**Holborn**  
**London WC1R 5DJ (GB)**

⑤④ **System for stabilizing the shapes of optical elements, exposure apparatus using this system and method of manufacturing semiconductor devices.**

⑤⑦ A temperature distribution of an object, such as an optical element (2), onto which radiation energy (1) is irradiated, is measured. The change of the shape of the object is controlled by varying the temperature of a part of the object on the basis of the measured temperature distribution to stabilize the shape of the object. Also, the shape of the object being irradiated is stabilized by causing the same temperature distribution in the object when in the thermally stable condition to be generated in the object while it is being irradiated. If the shapes of masks used to manufacture semiconductor devices are stabilized by using the above methods, highly integrated semiconductor devices can be manufactured.



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used.

X-rays are generated from the samarium target 13 by setting the excimer laser energy to be 50 mJ/pulse and the repetition frequency to be 300 Hz, and irradiated onto the surface of the reflection type mask 17. The curve c in Fig. 4 indicates the temperature distribution on the surface of the mask measured at this time by an infrared camera 22. As shown in Fig. 4, the temperature distribution is almost symmetrical, and it can be noted that the temperature in the central portion of the mask is 1.2°C greater than in the peripheral portion.

When the image of the mask is formed on the wafer on which a resist is applied at the wafer position 20 or thereabout and evaluated at this time, there is an aberration of approximately 10  $\mu\text{m}$  on the focal plane, and there is also a maximum image distortion of 0.01%.

Next, when electric current is supplied to the platinum resistance wires 21 on the reflection type mask 17 and to a heater 23a of the heating means 23 on the bottom of the mask 17, and when the amount of heating is adjusted while being monitored by the infrared camera 22, the substantially uniform temperature distribution indicated by the curve "d" in Fig. 4 is obtained. When the image formed condition is evaluated at this time by the same method as described above, there is an aberration of less than 2  $\mu\text{m}$  on the focal plane, and there is also an image distortion of less than 0.002%.

According to the embodiment described above, a method of stabilizing shapes of optical elements provides excellent advantages such that the amount that the shape of an optical element changes due to a non-uniform temperature increase is minimized and the deterioration of the optical performance of the optical element and the entire optical system is prevented. In addition, an optical apparatus using this method, can be achieved by providing temperature distribution measuring means and heating means for optical elements and by making the temperature distribution uniform during the light irradiation onto the optical element.

The present invention can be effectively applied to an optical apparatus having a high-intensity light source, such as a synchrotron radiation light source or a laser plasma X-ray source, the technology of which has been lately remarkably developed, and features that destruction of optical elements due to heat strain can be effectively prevented.

#### (Third Embodiment)

Fig. 5 is a schematic view illustrating the third embodiment. A convex mirror 101, which is a member of an X-ray exposure apparatus to be illuminated, is supported by a mirror holder 102 having a plurality of refrigerant flow passages 102a with its reflection sur-

face facing downward. Synchrotron radiation light (hereinafter referred to as "X-rays") radiated from a light emitting point (not shown) of a charged particle storage ring (hereinafter referred to as an "SOR ring") is reflected and expanded by the reflection surface of convex mirror 101. The expanded X-rays expose a perpendicularly held wafer 104. Since the exposure time control shutter for adjusting the exposure amount of the wafer 104 and masks are well known, an illustration of them is omitted in Fig. 5.

The temperature distribution on the mirror 101 is detected by a measuring means, such as an infrared camera 105. The detected value is corrected by a thermocouple 106 mounted on a portion where X-rays from the reflection surface of the mirror 101 are not incident. A temperature control apparatus for controlling the temperature distribution on the reflection surface of the mirror 101 comprises heating means, such as an infrared heater 107, a reflection plate 107a and a temperature control means, such as an aperture 108. The aperture 108 partially reduces or shuts off heat radiated from an infrared heater 107 by means of an adjustable opening and an infrared absorbing filter (not shown) disposed in the opening. The above opening and infrared absorbing filter are controlled on the basis of the values detected by the infrared camera 105 and the thermocouple 106. A predetermined temperature distribution is generated on the reflection surface of the mirror 101 by controlling the distribution of heat which reaches the reflection surface of the mirror 101 from the infrared heater 107. A control circuit 109 controls the output of the infrared heater 107 on the basis of the output from the infrared camera 105 and the thermocouple 106.

Next, an explanation will be given about an experiment carried out using the apparatus shown in Fig. 5.

X-rays radiated from an SOR ring having an accumulated current of 215 mA entered the reflection surface of a mirror having a curvature of 50 m at an incident angle of 2°. After a lapse of approximately one hour from the start of irradiation, the results of the temperature distribution on the reflection surface of the mirror and the distribution of the intensity of X-rays enlarged by the reflection surface and measured at the position of the wafer 104 are respectively shown by the solid line curve "a" in Fig. 6, and by the curve "c" in Fig. 7. The average energy absorbed by the mirror at this time was 50 mW/mm<sup>2</sup>.

Next, the irradiation of X-rays was stopped and the mirror returned to room temperature. After the opening of the aperture and the infrared absorbing filter were adjusted on the basis of the curve "a" in Fig. 6, the reflection surface of the mirror was heated by the infrared heater. After it was confirmed that the temperature distribution on the reflection surface thereof was thermally stable matching the curve "a" in Fig. 6, the irradiation of X-rays was restarted, at the

same time the heating by the infrared heater was stopped. Immediately after this, the temperature distribution on the reflection surface of the mirror and the intensity distribution of X-rays were measured again. The measured result of the temperature distribution are shown by the dashed-line curve "b" in Fig. 6. The results of measuring the intensity distribution of X-rays was substantially in agreement with the curve "c" in Fig. 7. At this time, the accumulated current of the SOR ring was 207 mA and the average energy absorbed by the mirror was 48 mW/mm<sup>2</sup>.

As can be understood from the above-described experiment, if the temperature distribution on the mirror's reflection surface reached the thermally stable state described above, a predetermined X-ray intensity distribution can be obtained without requiring a long standby time for thermal adjustment.

If X-ray exposure is continued, the X-ray intensity is lowered on the whole by the attenuation of the accumulated current of the SOR ring. However, in this embodiment, a decrease in temperature of the mirror's reflection surface is detected by continually monitoring the temperature on the surface by using an infrared camera and a thermocouple during X-ray exposure. Deformations of the reflection surface due to heat strain is prevented by adding heat from the infrared heater by means of the control circuit.

When X-ray intensity is lowered on the whole, all that is necessary is to increase the output of the infrared heater because the curved shape of the temperature distribution hardly changes though the overall temperature on the reflection surface of the mirror is lowered.

In this embodiment, the heating and cooling means can be used together in the same manner as in the first embodiment. This can be achieved by controlling the flow rate and temperature of each refrigerant in a plurality of refrigerant flow passages 102a.

#### (Fourth Embodiment)

Fig. 8 is a schematic view illustrating the fourth embodiment. In the same manner as in the third embodiment, the temperature distribution of a mirror of an X-ray exposure apparatus is controlled, and a decrease in accuracy due to heat strain of a mask which is a member to be illuminated is prevented by using the same means as the means for controlling the temperature distribution on the reflection surface of the mirror.

An X-ray enlarged by the same mirror (not shown) as in the third embodiment is passed through an opening of an exposure time control shutter 121 and irradiated onto a mask 122 formed of an X-ray transmission film 122a and an X-ray absorbing body 122b, thereby printing the mask pattern 122b on a resist 114a of a wafer 114. The mask 122 is supported by a mask support body 123. The temperature control

apparatus for controlling the temperature distribution on the photosensitive surface of the mask 122 comprises an apparatus (not shown) for detecting the temperature distribution of a temperature detecting device, such as an infrared camera, heating means, such as a pair of infrared heaters 124 and 125, reflecting plates 124a and 125a disposed in the infrared heaters 124 and 125, respectively, and temperature control means, such as apertures 124b and 125b, or shutters 124c and 125c. Both the apertures 124b and 125b are the same as those in the first embodiment. They are controlled by the output of a temperature detecting device, such as the aforesaid infrared camera, and cause a predetermined temperature distribution to be generated on the photosensitive surface of the mask 122.

The shutters 124c and 125c are moved in linkage with the exposure time control shutter 121 for controlling the exposure time at each position of the mask 122 and are controlled in such a way that only the surface of the mask 122 where X-rays are shut off by the exposure time control shutter 121 is selectively heated by the infrared heaters 124 and 125. That is, non-uniform temperatures which are periodically generated on the photosensitive surface of the mask 122 by the exposure time control shutter 121 are corrected by the shutters 124c and 125c of the infrared heaters 124 and 125, respectively.

Exposure was performed with the distance between a mask and a wafer being set at 70  $\mu$ m, and using a mask having a gold absorbing body formed on an X-ray transmission film of silicon nitride having a thickness of 2  $\mu$ m. The pattern strain of the exposed wafer was 0.08  $\mu$ m. Next, when an experiment was performed under the same conditions as described above without using the means for controlling the temperature distribution of the mask, the pattern strain was 0.023  $\mu$ m.

#### (Fifth Embodiment)

Fig. 9 illustrates the fifth embodiment. A member to be illuminated of this embodiment is a demagnification mirror of a soft X-ray reduction projection exposure apparatus.

An excimer laser light beam 131 is condensed by a lens 132 and irradiated onto a target 133 made of a samarium (Sm) material, causing a laser plasma X-ray 134 to be generated from the target 133. The X-ray 134 passes through a silicon filter 135 and an aperture 136 and is irradiated onto a reflection type mask 137. Furthermore, the X-ray 134 reflected by the reflection type mask 137 is reflected by a demagnification mirror 138, is passed through a shutter 139a, and forms the image of the reflection type mask 137 on a wafer 139. A holder 140 of the reflection type mask 137 has a plurality of refrigerant flow passages 141 for cooling the reflection type mask

137. The demagnification mirror 138 is similarly cooled indirectly by a plurality of refrigerant flow passages 143 of a mirror holder 142.

The temperature distribution on the photosensitive surface of the demagnification mirror 138 is measured by a measuring means, such as an infrared camera 146. The measured value is corrected by a thermocouple 147 arranged adjacent to the photosensitive surface of the demagnification mirror 138. The heating means, such as a glow bar lamp 144, heats the photosensitive surface of the demagnification mirror 138. Heat radiated from the glow bar lamp 144 is partially shut off or reduced by an aperture 145 which is the same as that of the first embodiment, causing a predetermined temperature distribution to be generated on the photosensitive surface of the demagnification mirror 138.

The operation of this embodiment is as described below.

First, the temperature distribution on the photosensitive surface of the demagnification mirror 138 in a thermally stable state of the demagnification mirror 138 while the wafer 139 is being exposed is measured by the infrared camera 146 and the thermocouple 147. The shift of a focus position due to the heat strain of the demagnification mirror 138 in this condition is measured. At the start of exposing the wafer 139, the aperture 145 is adjusted according to the measured temperature distribution on the photosensitive surface of the demagnification mirror 138, and the position of the wafer 139 is adjusted according to the shift of the focus position of the demagnification mirror 138. It is confirmed that the photosensitive surface of the demagnification mirror 138 has reached a predetermined temperature distribution by heating by the glow bar lamp 144, and thereafter exposure is initiated.

Since the demagnification mirror 138 is in a substantially thermally stable state at the start of exposure, standby time for thermal adjustment is hardly required. In addition, since a positional shift of the focus due to the heat strain of the demagnification mirror 138 is corrected, no blurring of a transfer pattern occurs.

In this embodiment, the heating and cooling means can be used together by controlling the flow rate and temperature of a refrigerant in each of the flow passages 141 and 143.

In the third and fourth embodiments, since a mirror and a mask, both of which are members to be illuminated, are made of a silicon carbide (SiC) material, the photosensitive surface of the members to be illuminated can be effectively heated by using an infrared lamp which emits infrared rays having a wavelength of 2 to 30  $\mu\text{m}$  for an infrared heater.

In the fifth embodiment, since a demagnification mirror, which is a member to be illuminated, is made of quartz, quartz having a low heat conduction coef-

ficient can be effectively heated by using a glow bar lamp which emits infrared rays having a wavelength of or above 4  $\mu\text{m}$ .

## (Sixth Embodiment)

An explanation will be given below about a method for manufacturing semiconductor devices by using the exposure apparatus described above.

Fig. 10 is a flowchart showing the sequence of the operation of manufacturing semiconductor devices (semiconductor chips, such as integrated circuits (ICs) or large scale integrated circuits (LSI circuits), liquid-crystal panels, or charge-coupled devices (CCDs)). Referring to the flowchart shown in Fig. 10, in step 1 (circuit design), circuits of semiconductor devices are designed. In step 2 (manufacture of masks), masks having designed circuit patterns formed thereon are manufactured. In step 3 (manufacture of wafers), wafers are manufactured by using materials, such as silicon. Step 4 (wafer process) is called a pre-step, whereby actual circuits are formed on wafers by lithography technology by using the masks and wafers produced as described above. The subsequent step 5 (fabrication) is called a post step, whereby semiconductors are formed into chips by using the wafers manufactured in step 4. This step includes an assembly step (dicing, bonding), a packaging step (enclosing chips), and the like. In step 6 (inspection), an inspection test for confirming the operations of semiconductor devices manufactured in step 5, or a durability test, is performed. Semiconductor devices are completed through the processes described above and shipped (step 7).

Fig. 11 shows a detailed flowchart for the wafer process. In step 11 (oxidation), the surface of the wafer is oxidized. In step 12 (chemical vapor deposition (CVD)), an insulating film is formed on the surface of the wafer. In step 13 (electrode formation), electrodes are formed on the wafer by deposition. In step 14 (ion implantation), ions are implanted into the wafer. In step 15 (resist process), a photosensitizing agent is applied to the wafer. In step 16 (exposure), a circuit pattern of the mask is printed and exposed to the wafer by means of the exposure apparatus described above. In step 17 (development), the exposed wafer is developed. In step 18 (etching), portions other than the developed resist image are etched. In step 19 (resist peel-off), resists which become unnecessary after etching is performed are removed. By performing these steps repeatedly, a circuit pattern is formed on the wafer in multilayered form.

Highly-integrated semiconductor devices which are difficult to manufacture before can be manufactured by the use of the manufacturing method of this embodiment.

Many different embodiments of the present invention may be constructed without departing from

the spirit and scope of the present invention. It should be understood that the present invention is not limited to the specific embodiments described in this specification. To the contrary, the present invention is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the claims. The following claims are to be accorded a broad interpretation, so as to encompass all possible modifications and equivalent structures and functions.

## Claims

1. A method of stabilizing shapes of objects, comprising the steps of:  
     measuring a temperature distribution of an object irradiated with radiation energy; and  
     causing the temperature of a part of the object to be changed on the basis of the measurement to control the change of shape of the object.
2. A method of stabilizing shapes of objects, comprising the step of:  
     determining a temperature distribution of a mask in a thermally stable state; and  
     controlling the temperature distribution of the mask being irradiated with radiation energy to be the same as the temperature distribution in the thermally stable state.
3. An optical apparatus, comprising:  
     an optical element;  
     means for irradiating said optical element with radiation energy;  
     measuring means for measuring the temperature distribution of the optical element; and  
     temperature control means for changing the temperature of a part of said optical element on the basis of the measurement by said measuring means.
4. An optical apparatus according to Claim 3, wherein said temperature control means comprises a heater.
5. An optical apparatus according to Claim 3, wherein said temperature control means comprises a cooler.
6. An optical apparatus according to Claim 4, wherein said heater is disposed on a rear side of said irradiated optical element.
7. An optical apparatus according to Claim 4, wherein said heater is an infrared heater which irradiates infrared rays onto a surface of said irra-

diated optical element.

8. An optical apparatus according to Claim 7, further comprising adjustment means including a member for absorbing infrared rays.
9. An exposure apparatus, comprising:  
     transfer means for exposing and transferring an exposure pattern to an object to be exposed by irradiating exposure energy onto a mask having an exposure pattern formed thereon;  
     measuring means for measuring the temperature distribution of the mask; and  
     temperature control means for changing the temperature of part of the mask on the basis of the measurement by said measuring means.
10. An exposure apparatus according to Claim 9, wherein the mask is a reflection type mask having an exposure pattern formed on the surface of a mirror.
11. An exposure apparatus according to Claim 9, wherein the exposure pattern includes a circuit pattern of a semiconductor device.
12. A method of manufacturing semiconductor devices, comprising the steps of:  
     preparing a reflection type mask having a circuit pattern formed thereon;  
     measuring the temperature distribution of the mask; changing the temperature of a part of the mask on the basis of the measurement to obtain a substantially uniform temperature distribution of the mask; and  
     exposing and transferring a circuit pattern of the mask onto a wafer by irradiating the mask with exposure energy.
13. A method of manufacturing semiconductor devices, comprising the steps of:  
     preparing a reflection type mask having a circuit pattern formed thereon;  
     determining a temperature distribution of the mask in a thermally stable state when the mask is being irradiated before the mask is irradiated with exposure energy; and  
     exposing and transferring a circuit pattern of the mask onto a wafer by irradiating the mask with exposure energy.
14. Semiconductor devices manufactured by a manufacturing method comprising the steps of:  
     preparing a reflection type mask having a circuit pattern formed thereon;  
     measuring the temperature distribution of the mask;

changing the temperature of a part of the mask on the basis of the measurement to obtain a substantially uniform temperature distribution of the mask; and

exposing and transferring a circuit pattern of the mask onto a wafer by irradiating the mask with exposure energy.

15. Semiconductor devices manufactured by a manufacturing method comprising the steps of:

preparing a reflection type mask having a circuit pattern formed thereon;

determining a temperature distribution of the mask in a thermally stable state when the mask is being irradiated before the mask is irradiated with exposure energy; and

exposing and transferring a circuit pattern of the mask onto a wafer by irradiating the mask with exposure energy.

16. A method of stabilizing shapes of objects comprising measuring a temperature distribution of an object, such as an optical element (2), onto which radiation energy is irradiated, and changing the shape of the object in a controlled manner by varying the temperature of a part of the object on the basis of the measured temperature distribution to stabilize the shape of the object.

17. A method as claimed in claim 16, characterised in that the shape of the object being irradiated is stabilized by causing the same temperature distribution in the object when in the thermally stable condition to be generated in the object while it is being irradiated.

18. A method of stabilizing shapes of objects, comprising the steps of:

measuring a temperature distribution of an object irradiated with radiation energy; and

causing the temperature of a part or whole of the object to be changed on the basis of the measurement to control the change of shape of the object.

19. A method of stabilizing shapes of a mask used in the manufacture of semiconductors, comprising the step of:

determining a temperature distribution of the mask in a thermally stable state; and

controlling the temperature distribution of part or whole of the mask being irradiated with radiation energy to be the same as the temperature distribution in the thermally stable state.

20. An optical apparatus, comprising:

an optical element;

means for irradiating said optical element

with radiation energy;

measuring means for measuring the temperature distribution of the optical element; and

temperature control means for changing the temperature of a part or whole of said optical element on the basis of the measurement by said measuring means.

FIG. 1

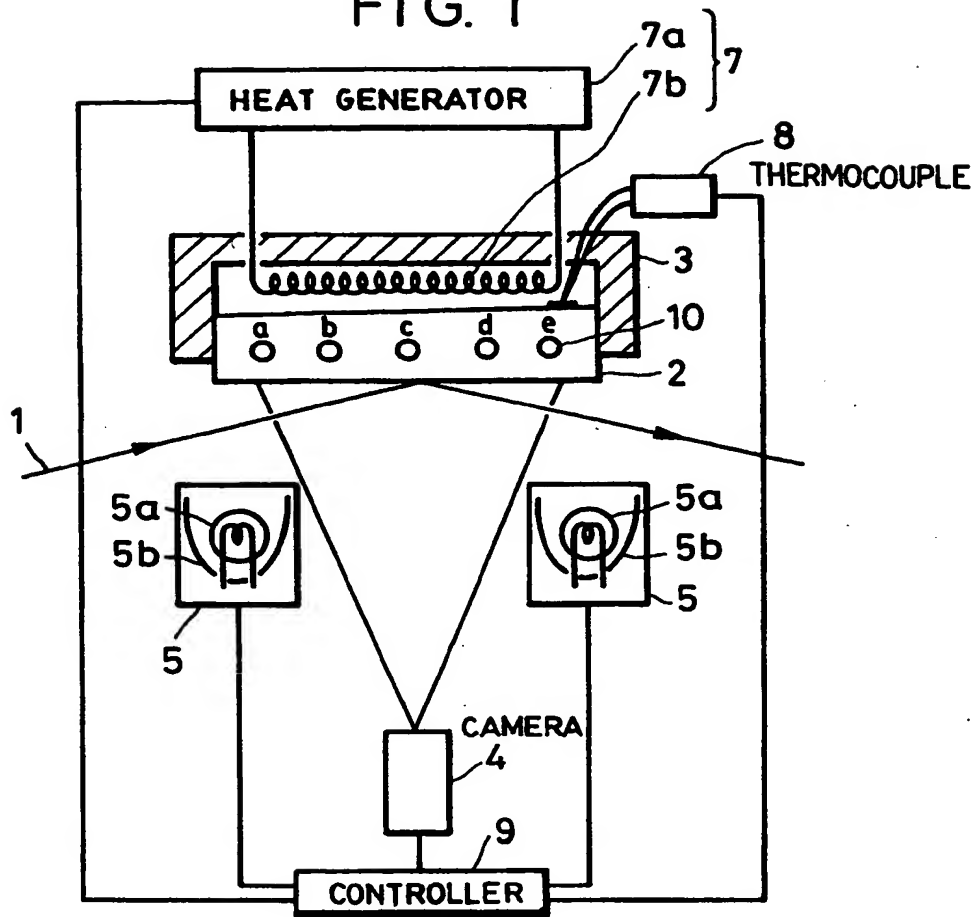


FIG. 2

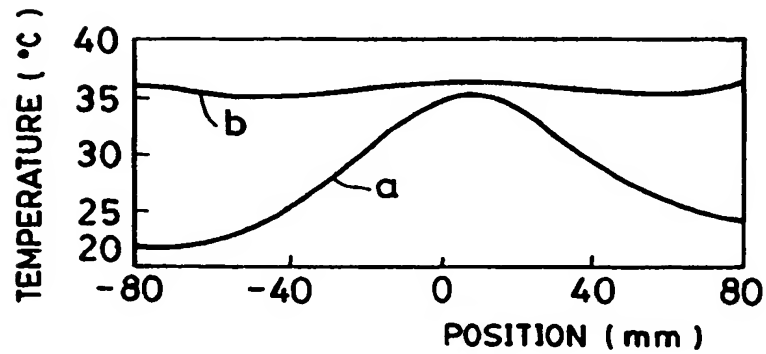


FIG. 3

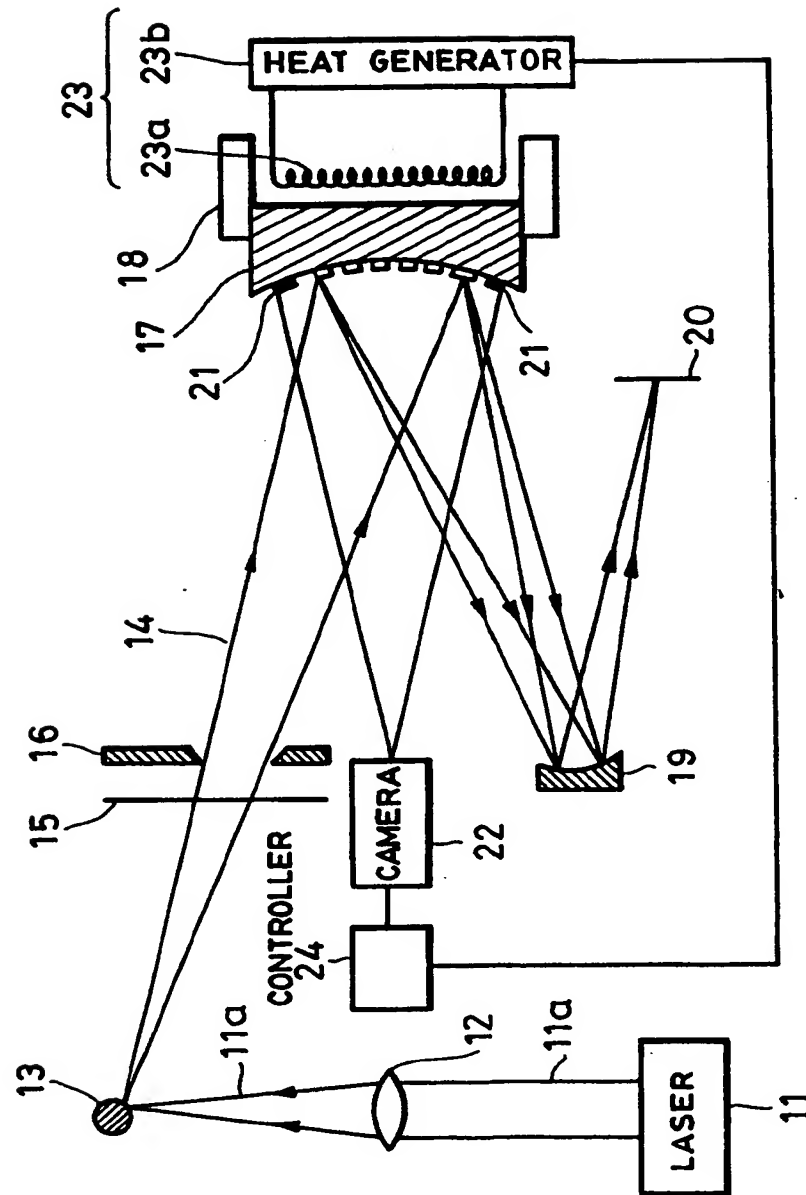




FIG. 4

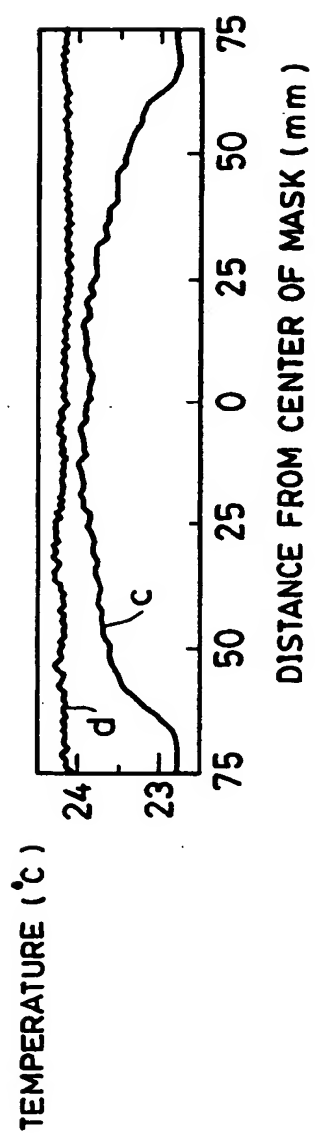


FIG. 5

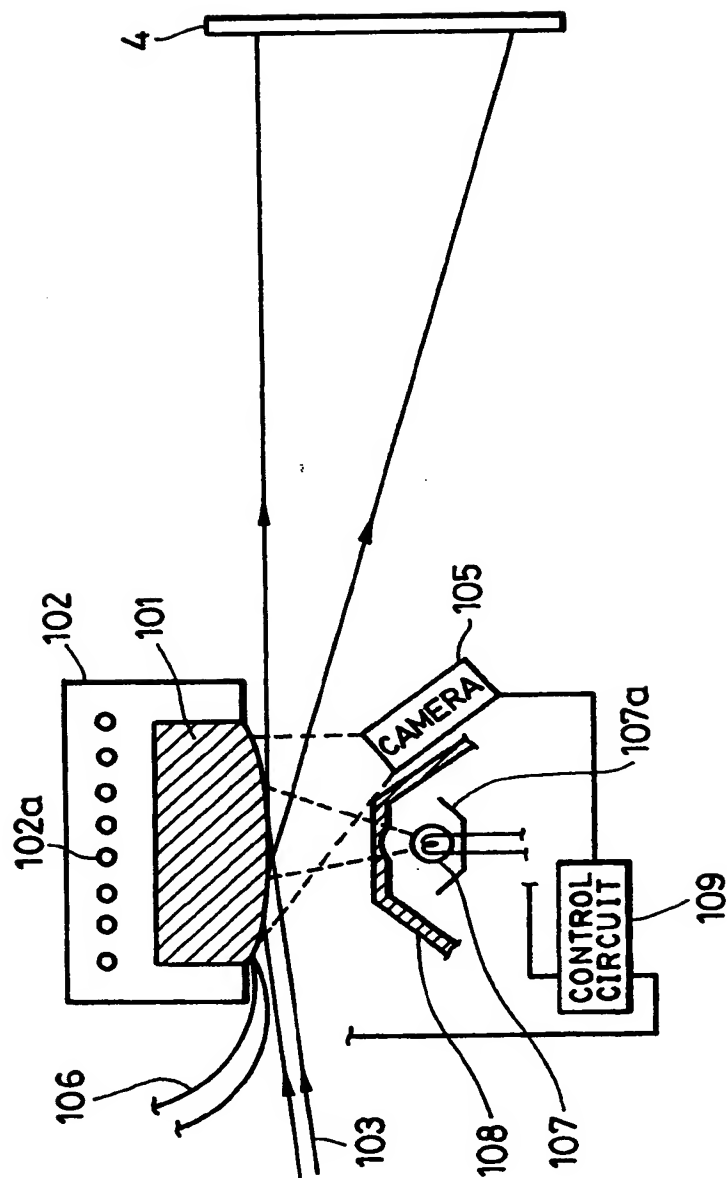


FIG. 6

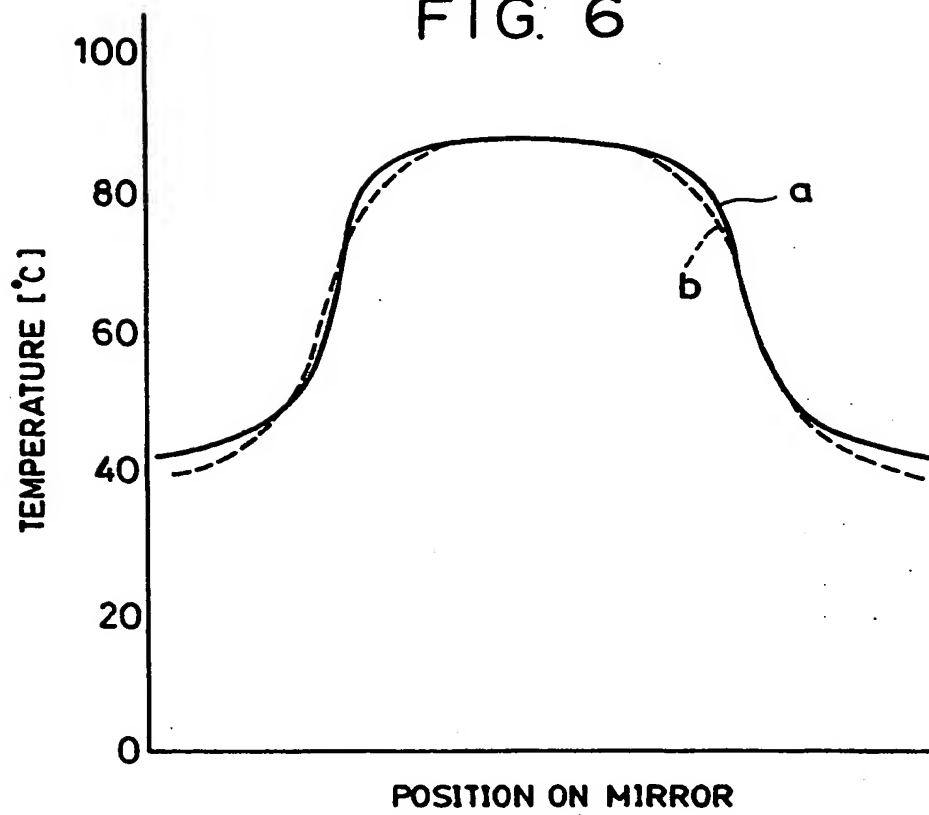


FIG. 7

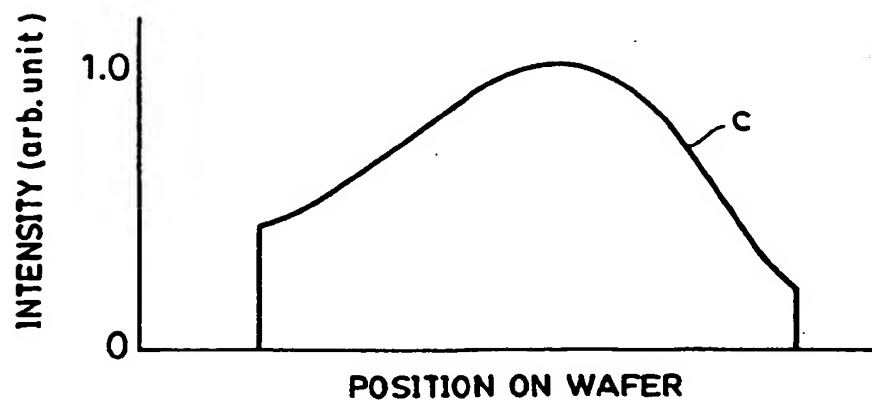


FIG. 8

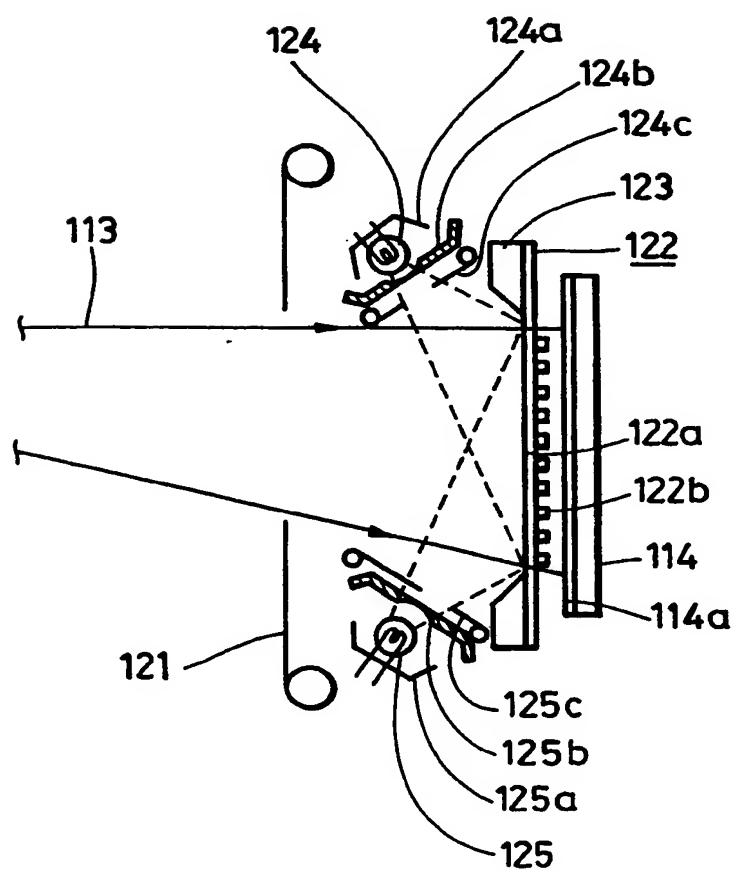


FIG. 9

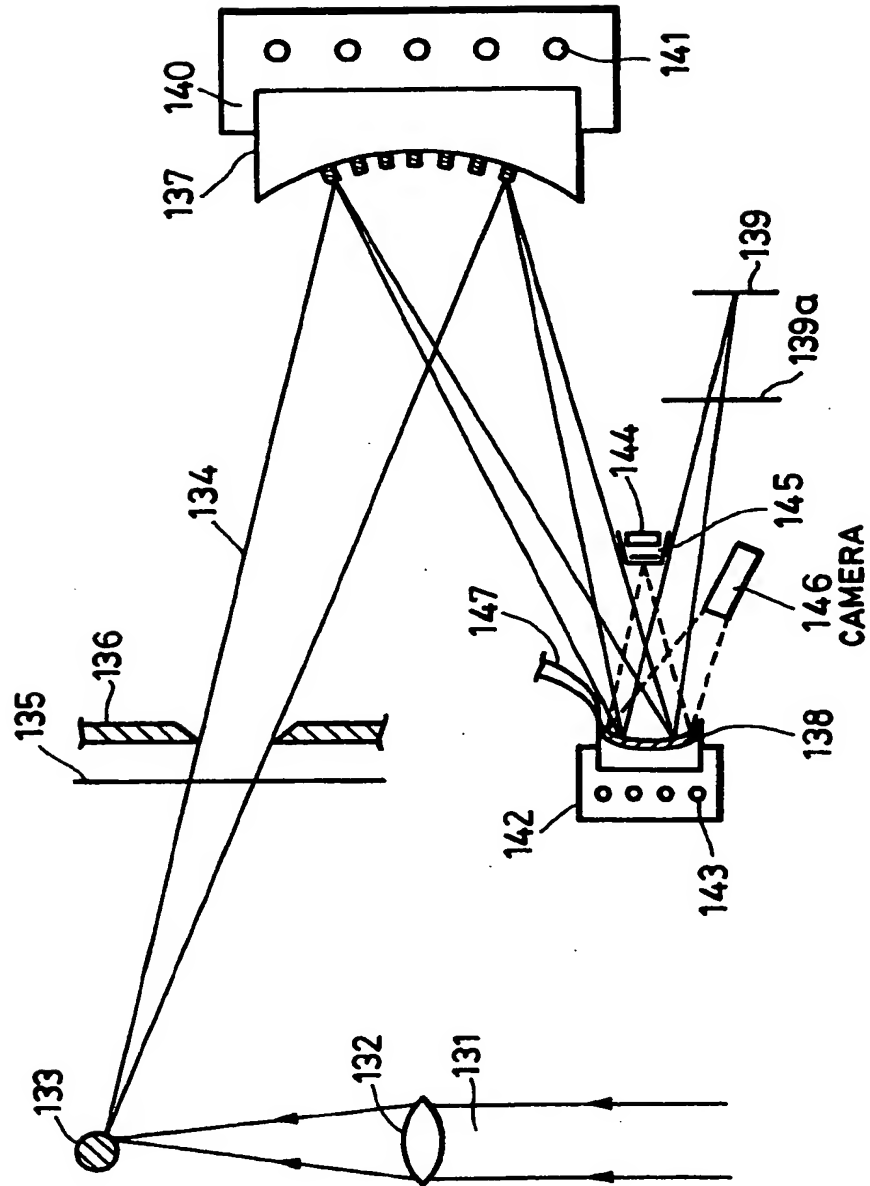


FIG. 10

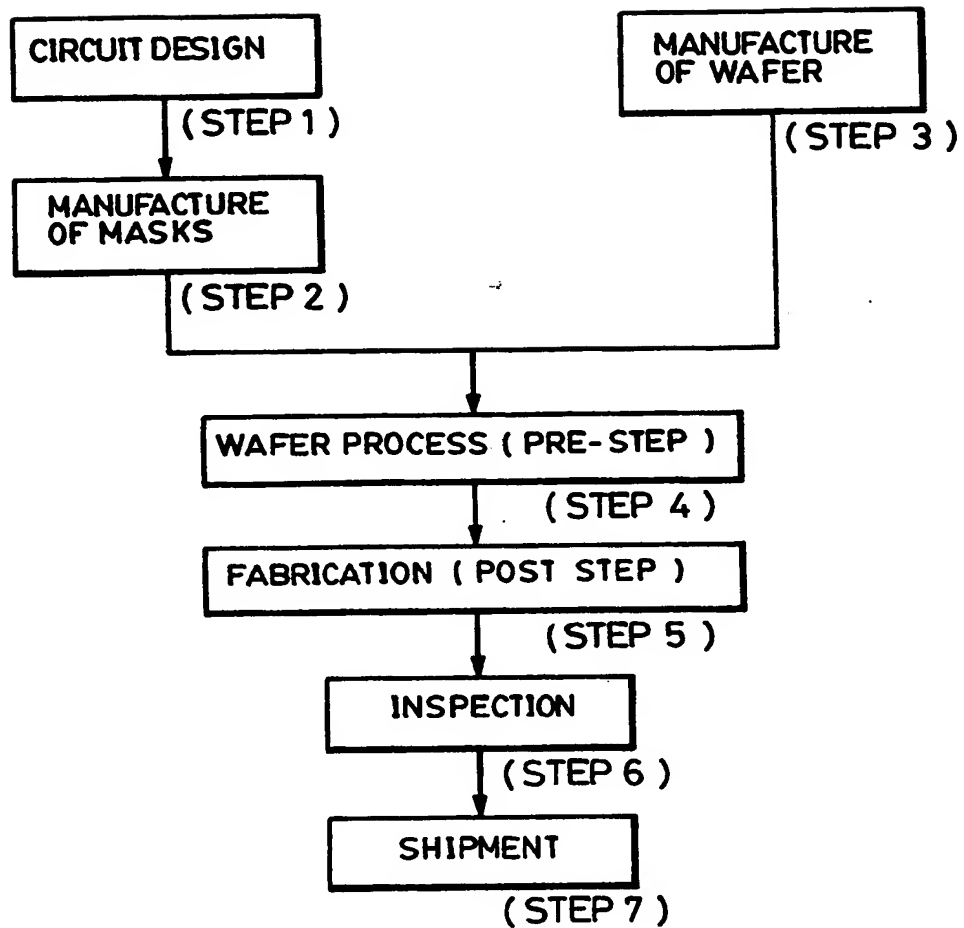
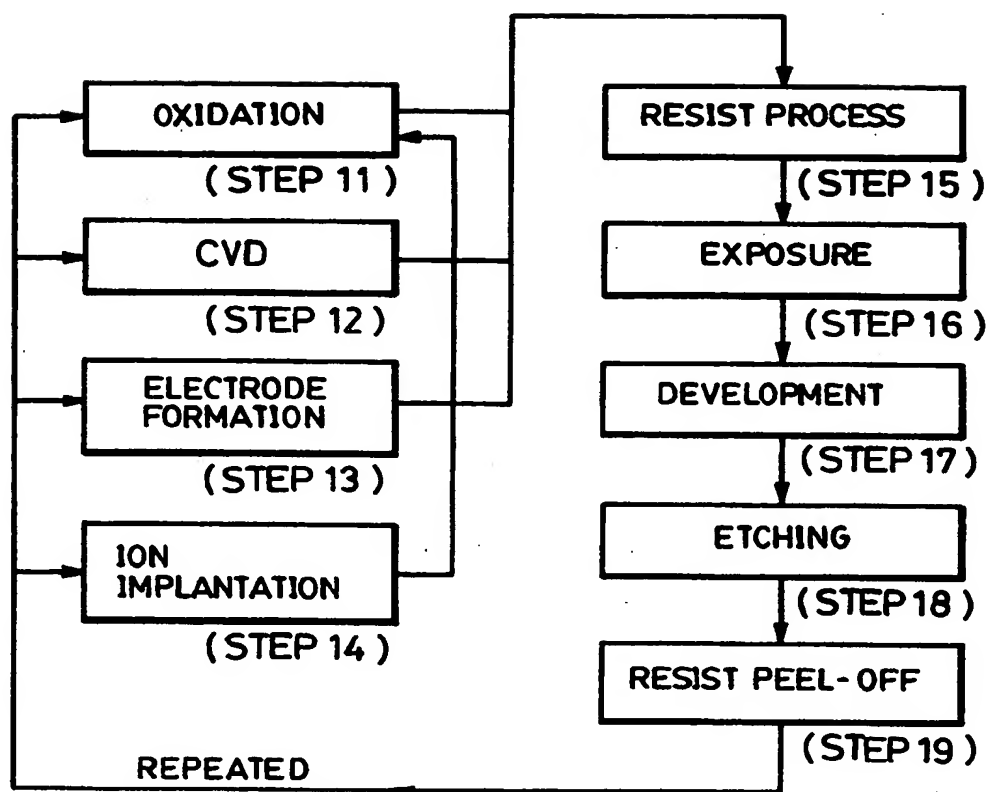


FIG. II





European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number

EP 92 30 8030

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	PATENT ABSTRACTS OF JAPAN vol. 013, no. 235 (E-766)30 May 1989 & JP-A-01 041 215 ( S H A R P C O R P ) 13 February 1989	1-3,5,9, 11,16-20	G03F7/20
Y	* abstract *	4,6,7, 10,12-15	
Y	IBM TECHNICAL DISCLOSURE BULLETIN. vol. 26, no. 7A, December 1983, NEW YORK US page 3261 ASCH ET AL. 'METHOD OF KEEPING A PROXIMITY PRINTING MASK AT A CONSTANT TEMPERATURE'	4,6,7	
Y	JOURNAL OF VACUUM SCIENCE AND TECHNOLOGY: PART B. vol. 7, no. 6, November 1989, NEW YORK US pages 1702 - 1704 , XP117194 HAWRYLUK ET AL. 'Reflection mask technology for x-ray projection lithography' * page 1703, right column *	6,10, 12-15	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			G03F
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 15 DECEMBER 1992	Examiner HERYET C.D.
<p><b>CATEGORY OF CITED DOCUMENTS</b></p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons</p> <p>&amp; : member of the same patent family, corresponding document</p>			

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